

(NASA-CR-199789) IMPACT OF  
GEOSTATIONARY SATELLITE WATER VAPOR  
CHANNEL DATA ON WEATHER ANALYSIS  
AND FORECASTING (Wisconsin Univ.)  
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**IMPACT OF GEOSTATIONARY SATELLITE WATER VAPOR CHANNEL DATA  
ON WEATHER ANALYSIS AND FORECASTING**

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## 1. INTRODUCTION

Recent studies have demonstrated the feasibility of deriving wind information from animated sequences of geostationary water vapor imagery in order to supplement conventional observations (Laurent 1993; Velden 1993; Holmlund 1993). Further work has examined the impact of these data on numerical weather prediction (NWP), and results suggest useful and complimentary upper-tropospheric wind information can be provided by these observations (Velden et al. 1993, Velden et al. 1994).

Development of algorithms at CIMSS to extract quantitative wind information from geostationary satellite water vapor data has progressed to the stage of quasi-operational testing and demonstrations. Full-disk wind sets derived from two different satellites (GOES-7 and Meteosat-3) were routinely produced on a twice-daily basis in March-April 1994, and delivered to NMC and ECMWF for assimilation into research versions of their respective global assimilation systems. In addition, the wind sets were included in real-time assimilations using the CIMSS regional-scale model to assess finer-scale impacts on NWP. Preliminary impact results included here are encouraging, and the full assessment along with case study evaluations will be presented at the conference.

With the recent successful launch of GOES-8, analysts and forecasters in the U.S. can expect satellite observations and products of

unprecedented quality. One big improvement will be realized in the widely-utilized water vapor channel. The combination of higher resolution and reduced signal-to-noise will lead to an improved qualitative presentation for subjective analyses, but also should translate into superior quantitative products such as water vapor tracked winds. At the time of writing, GOES-8 imagery was just becoming available. First results of tracking GOES-8 water vapor features are reported on in this paper, with further findings and applications to NWP to be presented at the conference.

## 2. BACKGROUND

Wind vectors derived from water vapor imagery are generated following the same general philosophy as with cloud drift wind tracking. Targets (structures in the imagery) are identified and tracked from successive images to derive motions (vectors), which are then assigned heights based on a best match between radiances (brightness temperatures) and a first guess temperature profile. In most cases, this height assignment will be representative of the layer of moisture being tracked, since the individual pixel radiances are achieved through contributions of energy over the depth of the attendant weighting function. Most vectors are assigned tropospheric pressure-heights in the 200-500 mb range, with a peak near 300-350 mb. As a final step, an objective quality control procedure is invoked once the wind vector field has been derived (Hayden and Velden 1991). Procedures to derive wind sets have become fully automated (Merrill et al. 1991; Holmlund 1993), and it has been demonstrated these data sets

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can be created on a time scale commensurate with real time operations.

Evaluation of the water vapor winds has centered on two approaches; statistical validation against rawinsondes, and model impacts. This paper focuses on the latter. Earlier studies have shown the water vapor tracked wind estimates to be comparable in quality to upper-tropospheric operational cloud tracked winds (Laurent 1993), with RMS values of 6.5-8 m/sec, and speed biases of less than 1 m/sec compared to collocated rawinsondes (Velden 1993; Velden et al. 1994). It was also demonstrated by Velden et al. 1994 that horizontal coverage is complimentary to wind information obtained through cloud tracking, and there is good consistency between observations derived from different satellites.

A first attempt to assess the potential importance of the water vapor tracked wind information on NWP was reported in Velden et al. 1993. In their study, a barotropic hurricane track forecast model was used to examine the impact of the winds on the analyses of Atlantic hurricane steering currents, and subsequent track forecasts. Modest improvements in track forecasts (relative to operational runs) were noted with the inclusion of the water vapor winds into the deep layer mean wind analyses which initialized the model. This was demonstrated by the fact that eleven out of fourteen 72 hr forecasts were improved, with a decrease in the mean forecast error of 8.2%.

### 3. IMPACT ON REGIONAL AND GLOBAL ANALYSES AND FORECASTS

Wind sets produced by CIMSS for a trial period in March-April 1994 (as described in Velden et al. 1994) were transmitted to NMC for model impact tests. NMC conducted the exercise using a T62 version of the global spectral model (similar to T126 AVN/MRF). Forecasts produced from analyses initialized with the water vapor winds are compared to operational forecasts in order to assess model impact. Shown in Table 1 are comparisons of results from 72-h forecasts for a 15-day subset of the trial period. The forecast fields are verified against model analyses. Two latitude-dependent domains are considered in order to examine regional impacts.

Table 1. Impact of water vapor motion wind data on 72-h forecasts from the NMC global spectral model during a 15-day trial period in March, 1994.

60N-60S			
	opn	exp	fsp exp/opn
200mb vector rms (m/s)	12.00	11.86	9/6
200mb acpsi	.809	.815	9/6
200mb acv	.741	.742	8/7
20N-20S			
200mb vector rms	10.51	10.22	9/6
200mb acpsi	.654	.681	12/3
200mb acv	.541	.550	8/7

opn = operational runs

exp = experimental runs with water vapor winds

fsp = frequency of superior predictions

acpsi = anomaly correlation of stream function

acv = anomaly correlation of v-component

Considering first the near-global domain, the impacts are not dramatic, as might be expected since the wind coverage over the mid latitudes is limited. It should also be noted that the wind sets produced by CIMSS cover only a portion of the western hemisphere, while the verification statistics are global, further limiting the potential impact. Despite these caveats, the impacts are slightly positive in all parameters examined. 9 of the 15 forecasts were improved, with a slight reduction in the overall 200 mb wind vector rms.

Greater impact is seen in the tropical band, a region of sparse conventional data, and abundant water vapor wind coverage. While still modest, a more substantial gain in forecast accuracy is noted, especially considering the rotational component of the wind (psi). For this particular parameter, 12 of the 15 forecasts were improved. These results suggest the winds are contributing to a better definition of circulations or wave-like features in the ITCZ region.

The water vapor wind sets were also provided to ECMWF for their evaluation. While

acknowledging the impressive coverage of the winds (Graeme Kelly, personal communication), ECMWF had not yet accomplished a rigorous model impact test at the time of this writing. However, plans are to evaluate the impact of the winds using a new 3D-VAR version of their global model, and these results will be presented at the conference.

It is of interest to also examine the impact of the winds on regional scales. To accomplish this, forecast impact tests were conducted using the CIMSS regional assimilation system (CRAS), which is an adaptation of the Australian Bureau of Meteorology operational regional forecast model (Leslie et al. 1985). The model analysis covers a North American and adjacent waters domain at 150 km horizontal resolution, with 39 vertical levels. The forecast model operates with 20 vertical levels. Within the model package, a 3-D variational wind-mass adjustment routine is activated in areas lacking in mass information (i.e. oceanic regions). This routine essentially spreads the relative wealth of wind information onto the mass field through gradient balance adjustments. Experimental forecasts (EXP) including the water vapor winds are compared to control runs (CON) which contain only operationally available data.

An example of data impact on the model analysis and forecast fields is illustrated in Figs. 1 and 2, respectively. Shown in Fig. 1 is a plot of the 275-325 mb water vapor winds (large vectors) for 00 UTC on 22 March 1994. It should be noted that winds were only produced over marine areas. The vectors are overlain on a 300 mb model wind analysis difference field (EXP - CON), indicated by the smaller barbs (a barb length of one grid point interval equals 8 m/sec). As can be seen, differences at this particular level are modest, but can be as great as 6 m/sec such as in the trough off of the east coast of the U.S.

These analysis differences translate into 48-h forecast differences shown in Fig. 2. The 48-h EXP forecast 300 mb height field is overlain to show the large-scale pattern. In order to highlight the differences, in this figure a barb length of one grid point interval equals 5 m/sec. Fig. 2 shows small differences cover most of the domain, with notable differences in several locations including

the EXP forecast tendency to amplify the ridge over the central U.S.

Model impact results from CRAS forecasts of 19 cases from the March/April 1994 trial period reveal a trend similar to that found with the NMC impact study. In general, a modest but positive improvement in RMS and bias statistics of upper-level height and wind fields are noted. An example of the forecast impact (72 hr) in terms of RMS at 400 mb is given in Fig. 3. In this figure, a comparison of CON and EXP forecast RMS errors (versus rawinsondes) is presented as a CON minus EXP value (meters) for each case. Positive model forecast impacts (reduced RMS errors as indicated by cases above the 0 line) produced by the addition of the water vapor winds to the analyses are indicated in 12 of the 19 cases. Only 3 cases exhibit a degraded forecast, and 4 had virtually no impact. These results are fairly representative for mandatory levels between 200 and 500 mb, where the greatest impact would be expected due to the vertical distribution of the data.

The impact of the winds on the regional model forecasts appears to be highly case dependent. While the absolute forecast error improvements are not large in a domain-wide RMS sense, regional forecasts may be more significantly affected. Qualitative examination of the cases run with the CRAS model indicates greatest positive impact occurs with active patterns in the eastern Pacific (i.e. upper-level circulations or jet streaks). These active periods correspond to some of the positive impact peaks in Fig. 3. Often these systems are not adequately defined by operationally available data (i.e. aircraft reports or cloud tracked winds). For an example, see Velden et al. (1994).

#### 4. PRELIMINARY DATA FROM GOES-8

At the time of writing, data from GOES-8 were becoming available as part of system check-out. Although limited, observations were collected for several time periods in August 1994. Qualitatively, the GOES-8 water vapor imagery appears to be superior to the GOES-7 imagery, due to improved resolution (8 km vs. 16 km) and signal-to-noise. Wind algorithms were applied to extract water vapor vectors to assess (in a preliminary sense) and compare to GOES-7

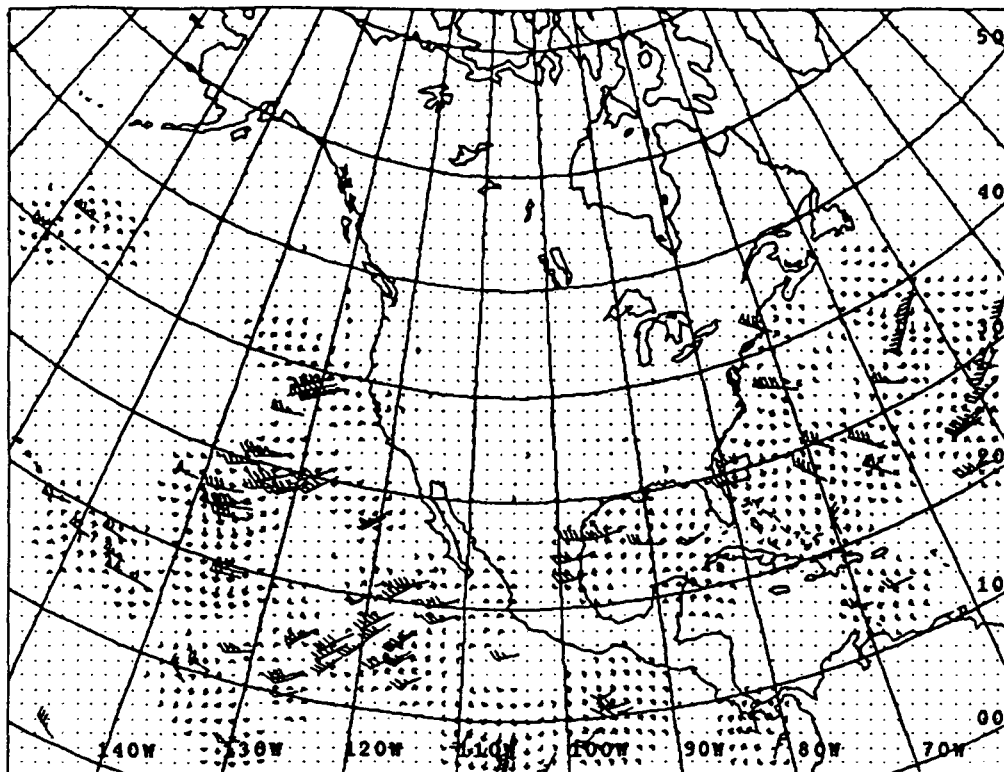


Fig. 1. Plot of 275-325 mb water vapor winds (large barbs, full stick = 5 m/sec and flag = 25 m/sec) over 300 mb CRAS wind analysis difference (EXP minus CON) field (arrow length of one grid length interval = 8 m/sec) for 00 UTC 22 March 1994.

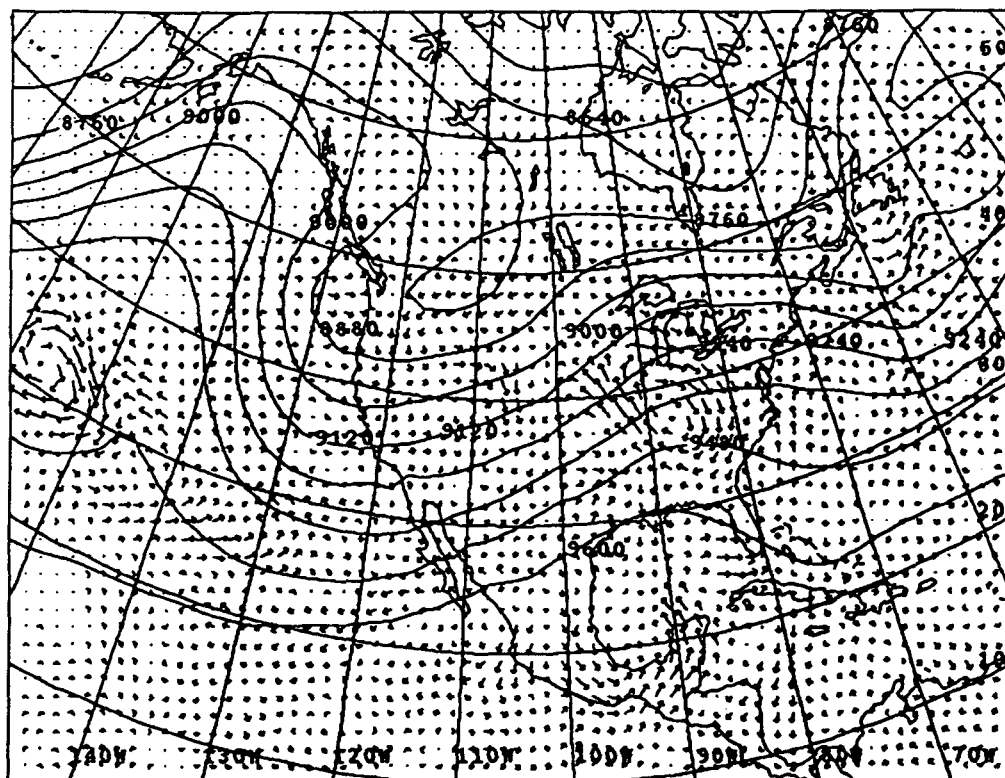


Fig. 2. Difference field (EXP - CON) from two CRAS 48 hr forecasts of 300 mb wind (arrow length of one grid interval = 5 m/sec) initialized at 00 UTC 22 March 1994. Also shown (contours in meters) is the 300 mb EXP height forecast.

# 72HR FCST 400MB HEIGHTS

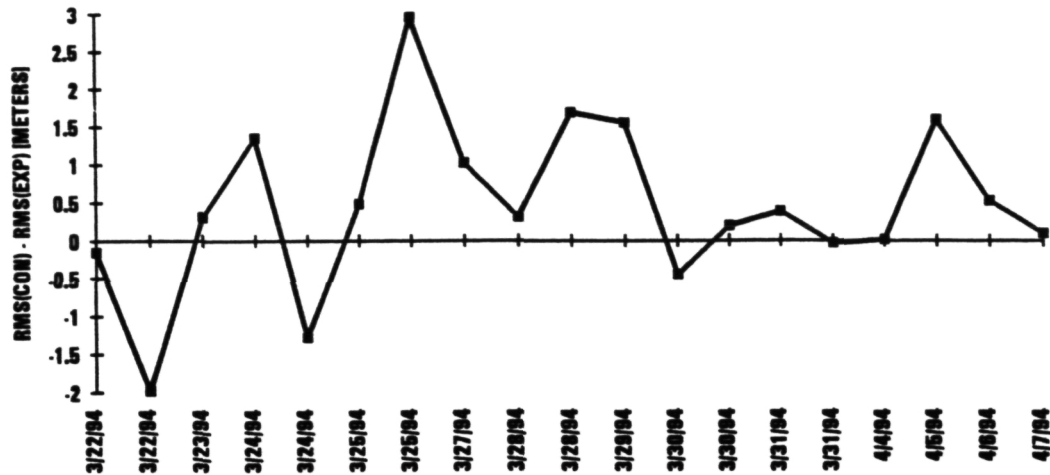


Fig. 3. Comparison of RMS errors (verified against rawinsondes) for CRAS model 72 hr forecasts of 400 mb heights for 19 cases in March/April 1994, expressed in terms of RMS(CON) minus RMS(EXP). Positive impact of the water vapor winds (EXP) is indicated in cases with points above the zero line. A few of the days contain multiple data sets (00 and 12 UTC).

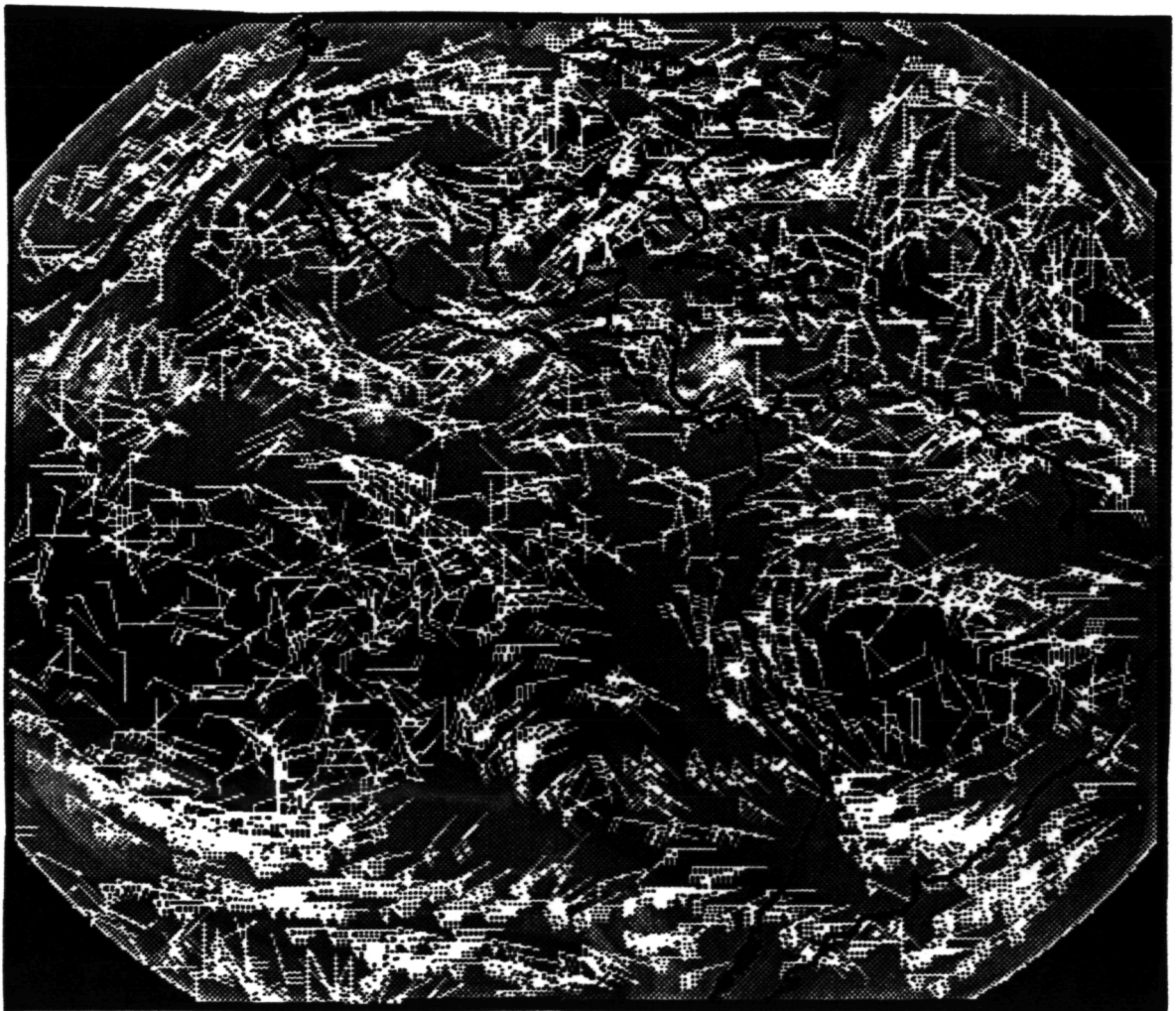


Fig. 4. Example of the horizontal coverage of water vapor winds attainable from GOES-8, plotted in knots over a GOES-8 water vapor image.

winds. An example of the typical coverage achieved with GOES-8 is shown in Fig. 4. Wind vector coverage is quite remarkable, and indicates a high degree of success in obtaining traceable features.

A limited inter-comparison of vector quality (GOES-8 vs. GOES-7) is shown in Table 2. For 7 days in August, collocated (space and time) wind vectors from each satellite were derived, quality-controlled and are compared to collocated rawinsondes. The results show a ~10% reduction in GOES-8 wind vector RMSE relative to GOES-7. While preliminary and limited, these results are quite encouraging. This assessment will continue as GOES-8 data become routinely available, and an update will be presented at the conference.

Table 2. Inter-comparison of GOES-8 and GOES-7 water vapor motion wind vectors verified against collocated rawinsondes for a 7 day period in August, 1994. NUM = number of comparisons. RMSE and BIAS are in m/sec.

	RMSE	BIAS	NUM
GOES-7	6.96	0.10	494
GOES-8	6.32	0.09	494

## 5. SUMMARY

Preliminary results from NWP impact studies are indicating that upper-tropospheric wind information provided by tracking motions in sequences of geostationary satellite water vapor imagery can positively influence forecasts on regional scales, and possibly on global scales as well. The data are complimentary to cloud-tracked winds by providing data in cloud-free regions, as well as comparable in quality. First results from GOES-8 winds are encouraging, and further efforts and model impacts will be directed towards optimizing these data in NWP. Assuming successful launches of GOES-J and GMS-5 satellites in 1995, high quality and resolution water vapor imagers will be available to provide nearly complete global upper-tropospheric wind coverage.

## Acknowledgments

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